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(54) Title of Invention: Polyester Bicomponent Staple Fibers for Fabrics

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## SPECIFICATION

### 1. Title of Invention

Polyester Bicomponent Staple Fiber for Fabrics

### 2. Claims

(1) Polyester bicomponent staple fiber for woven or knit fabrics with a special crimp morphology that is a polyester bicomponent staple fiber with revealed three-dimensional crimpability in which two polyester components, at least 85 mol% of whose repeating units are ethylene terephthalate, are bonded side-by-side, where this polyester staple fiber consists of two components having intrinsic viscosities of  $\leq 0.55$ , the component on one side exhibits higher orientation tension and shrinkage than the other component, and the strength characteristics of this staple fiber are a tenacity of 2.5-4.5 g/d and bending strength of  $\leq 1,500$  times, there is a straight section 5-30 mm long, which is 20-50%, as total length, of the overall fiber length and essentially does not manifest crimp by a heat treatment of  $\leq 180^{\circ}\text{C}$ , on at least one end of the staple fiber, the number of crimps of the crimped section is 8-15 per 25 mm, the degree of crimping is 15-35%, the crimping degree/number of crimps ratio is  $\geq 1.5$ , and the fiber length is  $\geq 50$  mm.

(2) The polyester bicomponent staple fiber for fabrics of Claim (1) wherein the difference between the intrinsic viscosities of the two components is 0.06-0.12.

(3) The polyester bicomponent staple fiber for fabrics of Claim (1) wherein the difference between the intrinsic viscosities of the two components is less than 0.05, ethylene-5-sodium sulfoisophthalate is copolymerized in a component on at least one side, and the difference in percentage copolymerization from that of the other component is  $\geq 1$  mol%.

(4) The polyester bicomponent staple fiber for fabrics of Claim (1) wherein the two components comprise polyethylene terephthalate having ordinary-pressure cationic dyeability copolymerized with 3-6 mol% of ethylene-5-sodium sulfoisophthalate, and the difference between the intrinsic viscosities of the two components is 0.05-0.10.

(5) The polyester bicomponent staple fiber for fabrics of Claim (1) wherein the difference between the intrinsic viscosities is  $\leq 0.05$ , ethylene terephthalate and trimellitic acid have been copolymerized for the component on at least one side, and the difference in percentage copolymerization from that of the other component is  $\geq 0.5$  mol%.

### 3. Detailed Description of the Invention

#### Field of technology

The present invention relates to a polyester bicomponent staple fiber for fabrics that has a special crimp morphology. More specifically, it relates to providing outstanding spinnability and spun yarn properties to a bicomponent staple fiber in which crimp is manifested three-dimensionally to a high degree and also providing outstanding touch, bulk, resilience, and pilling resistance to fabrics for clothing.

#### Prior art and problems

Aggregate of side-by-side type three-dimensional crimp polyester bicomponent staple fibers revealed in a high number of crimps and high degree of crimping has been utilized mainly for bedding (*futon*) filling in the past because it exhibits outstanding bulk due to its characteristic crimped structure. But when used as spun yarn for fabrics, numerous neps generate in the spun web in the spin carding process, and not only is spun yarn of satisfactory yarn quality not obtained, but in extreme cases there is a problem of the breaking of the web spun from the card, and at present it is not used for fabric applications.

Attempts have been made in the past to improve spinnability and yarn quality by reducing the degree of crimping of the bicomponent staple fiber to  $\leq 15\%$  in order to solve the above problems. But the drawback in this case was that sufficient bulk and resilience could not be imparted to the fabric.

Also, attempts have been made to produce spun yarn by providing latent crimp temporarily in the manufacturing process of the staple fibers and imparting the mechanical crimp necessary to improve spinnability and yarn quality and manifesting crimp at the fabric stage. But in this case, too, there was the drawback that sufficient crimping was not manifested in a state in which the single fibers were mutually restrained as in spun yarn or fabrics.

Also, in the case of fabrics that use staple fibers, the staple fiber is often dyed and subsequently converted into spun yarn, and in this case there was the drawback that the latent crimp became manifest during dyeing and troubles occurred in the spinning process. Also, when three-dimensional crimp bicomponent staple fibers were used in fabrics for clothing, that effect was manifested by clothing for fall and winter use that utilizes puffiness of the fabric, in addition to problems of spinnability and yarn quality, but the problem of fabrics for fall and winter use was that the spun yarn had few twists and there was much fluff on the fabric surface, and the polyester bicomponent staple fiber did not have sufficient pilling resistance.

Applying the method of lowering strength characteristics by reducing the degree of polymerization which is adopted for ordinary polyester staple fibers also to bicomponent staple fibers in order to improve pilling resistance is also conceivable. But the reality is that an effect of inhibiting pilling is hardly found in bicomponent staple with three-dimensional crimp at reductions in the degree of polymerization and strength characteristics of the extent usually adopted.

There is also a recent proposal to make pilling resistance and spinnability satisfactory by suppressing the tangling of fluff by straightening at least one end of the fibers and also making the number of crimps and degree of crimping of the crimped sections to 15 per 25 mm and 15% in Japanese Patent Application Kokai Publication Sho 56-118917 as a means of improving pilling resistance. But polyester bicomponent staple fiber does not satisfy spinnability and pilling resistance as well as bulk and resilience sufficiently in fabric applications for clothing.

Also, in Japanese Patent Application Kokai Publication Sho 58-87315 there is proposed a polyester staple fiber with three-dimensional crimp and also crimped and non-crimped sections as a feather-life [sic; like?] inner filling material. But this is used for bedding (*futon*) products by only blowing air without going through a carding process, and it does not improve spinnability, yarn quality, or pilling resistance for fabric applications.

#### Object of the invention

The first object of this invention is to provide a novel polyester bicomponent staple fiber for fabrics that does not lose the properties of side-by-side type polyester bicomponent staple fiber that reveal a high number of crimps and a high degree of crimping three-dimensionally, do not generate neps and web breakage in the spin carding process, and moreover excels in spun yarn quality.

The second object is to provide a polyester bicomponent staple fiber which has, in addition to outstanding spinnability and yarn quality, outstanding pilling resistance along with wool-like hand, bulk, resilience, and softness when converted into fabrics.

In addition, the third object is to provide a polyester bicomponent staple fiber that does not have reduced spinnability even if loose-stock dyed and also gives a fabric with outstanding hand, bulk, resilience, softness, and pilling resistance.

#### Constitution of the invention

The aforementioned objects of this invention are attained by the following constitution.

(1) It is a polyester bicomponent staple fiber for fabrics with a special crimp morphology that is a polyester bicomponent staple fiber with a revealed three-dimensional crimpability in which two polyester components, at least 85 mol% of the repeating units of which is ethylene terephthalate, are bonded side-by-side and this polyester staple fiber is characterized in that the two components have intrinsic viscosities of  $\leq 0.55$ , a component on one side exhibits higher orientation tension and shrinkage than the other component, the strength characteristics of the staple fiber are a tenacity of 2.5-4.5 g/d and a bending strength of  $\leq 1,500$  times, at least one end of the staple fiber has a straight section 5-30 mm long that is 20-50%, as total length, of the overall fiber length and essentially does not develop crimp by a heat treatment of  $\leq 180^{\circ}\text{C}$ , the number of crimps of the crimped section is 8-15 per 25 mm, the degree of crimping is 15-35%, the crimp degree/crimp number ratio is  $\geq 1.5$ , and the fiber length is  $\geq 50$  mm.

The constitution of this invention will now be explained in detail.

The repeating units of the two polyester components that make up the staple fiber of this invention are  $\geq 85$  mol% ethylene terephthalate. If the ratio of the ethylene terephthalate of the repeating unit is less than 85 mol%, the dimensional stability, stiffness, and tension characteristic of polyethylene terephthalate will be lost. Also, depending on the kind and amount of the components copolymerized, this will also lead to an extreme drop in  $T_g$  and have an adverse effect on pilling resistance, so it is preferred that  $\geq 90\%$  of the repeating units is ethylene terephthalate.

This invention is polyester bicomponent staple fiber with a revealed three-dimensional crimpability in which these polyesters are bonded side by side. The average intrinsic viscosity of the two bonded components is  $\leq 0.55$ , and a component on one side must be a component that exhibits higher orientation tension and shrinkage than the other component.

In this invention, intrinsic viscosity is the value found from the viscosity measured in  $25^{\circ}\text{C}$  *o*-chlorophenol, and the average intrinsic viscosity is the value of the viscosity of the bicomponent staple fiber as a whole found in the same way as intrinsic viscosity and is preferably  $\leq 0.52$  from the viewpoint of further improving pilling resistance. Also, the difference in intrinsic viscosity was found from the difference between the intrinsic viscosities of the respective component polymers.

An average intrinsic viscosity of  $\leq 0.55$  is essential in terms of the strength characteristics necessary for pilling resistance. In general, it is well known that three-dimensional crimpability is

manifested by bonding polyesters of different viscosities side-by-side. But in order to obtain the staple of high crimp number and high crimping degree of this invention by the manufacturing process of staple fibers, it is necessary to make both the orientation tension and shrinkage of a component on one side higher and reveal crimping fully by overcoming the mutual constraint of the fibers by a heat treatment in the relaxed state after drawing. It is therefore desirable that the fiber have an orientation tension of  $\geq 0.1$  g/d and a shrinkage of  $\geq 1\%$ .

In order to cause the pills that have formed to drop off easily while they are still small, the average intrinsic viscosity of the two components must be  $\leq 0.55$ , the bending strength  $\leq 1,500$  times, and the tenacity 2.5-4.5 g/d. These are more preferably  $\leq 0.52$ ,  $\leq 1,000$  times, and 2.5-4.0 g/d. However, if the average intrinsic viscosity of the two components is lower than 0.45 or the bending strength is lower than 150 times, this will lead to breakage of fibers in the spinning process and lowering of the abrasion resistance of the finished product, so neither situation is desirable. Also, if the tenacity falls below 2.5 g/d, these phenomena will be pronounced and the fibers will not be useable. If the bending strength is over 1,500 times and the tenacity is over 4.5 g/d, sufficient pilling resistance will not be obtained.

Also, the staple fiber of this invention must have a fiber length of  $\geq 50$  mm and must also have a straight section 5-30 mm long, which is 20-50%, as total length, of the overall fiber length and essentially does not develop crimp by a heat treatment of  $\leq 180^\circ\text{C}$ , on at least one end.

If the overall fiber length is less than 50 mm, the staple fiber with straight sections of this invention will cause an extreme drop in entangling and lead to lap licking in carding, web vibration, and web breakage, and handling will be difficult at the site of actual spinning and manufacture. Moreover, high-precision production of fibers with a straight section at one or both ends will be difficult. The preferred overall length of the fiber is  $\geq 60$  mm.

The preferred morphology of the straight sections in the fibers is either to have straight sections at both ends of the fiber as shown in Figure 1 or to have a straight section at only one end of the fiber as shown in Figure 2. When subjected to spinning, etc., as staple fiber aggregate, it may be a mixture of both of these morphologies. Also, fibers with crimped sections at both ends and a straightened center section and fibers with no straight section but only a crimped section may be mixed in this aggregate, but in terms of spinnability and pilling resistance, the ratio at which the two are mixed in the polyester staple fiber is preferably  $\leq 20\%$ .

But when there are straight sections at both ends, the total of the lengths of each (in Figure 1, the length obtained by adding  $S_1$  and  $S_2$ ) is regarded as the total length of the straight sections (hereinafter  $S_{\text{total}}$ ). When there is a straight section at only one end (Fig. 2), the length of that straight section is  $S_{\text{total}}$ . The actual length of the crimped section is  $W$ , and the length obtained by adding  $S_1$ ,  $S_2$ , and  $W$  is the overall fiber length  $L$ .

If the total length of the straight section is less than 20% of the overall fiber length and also if the total length of the straight section is less than 5 mm, it will lack the effect of lowering excess entangling and reduce the effect of inhibiting the tangling of fluff. If the total length is over 50% and also if the total length of the straight section is over 30 mm, this will conversely lower the entangling excessively and cause lap licking in carding, web vibration, and web breakage, so neither situation is desirable. The more preferred range of the length of the straight sections is 30-43% of the overall fiber length.

When the polyester staple fiber is spun after loose-stock dyeing, troubles in spinning will be unavoidable if crimp is manifested in the straight sections by heat during that dyeing. As will be discussed below, in the case of fabrics made from polyester staple fibers, a decline in pilling resistance will be brought about if crimp is manifested by the finishing set in the dyeing and finishing processes to improve dimensional stability. The conditions of wet heat up to 130°C and dry heat up to 180°C, respectively, are adopted for the dyeing and finishing set of polyester staple fibers, so crimping of the straight section must not be produced by a heat treatment of at least up to 180°C.

The crimping properties of the crimped section have an important relationship to the touch, bulk, and resilience of the fabric. In order to provide the proper degree of entangling in the carding process from the viewpoint of spinnability, the number of crimps must be 8-15 per 25 mm, the degree of crimping must be 15-35%, and the crimp degree/crimp number ratio must be  $\geq 1.5$ .

If the number of crimps is over 15 per 25 mm, the depth between the ridges of the crimp will be small and entangling will conversely decline, and in addition, even though the bulk of woven fabric is improved, this will cause a decline in softness and compressibility. If the number of crimps is fewer than 8 per 25 mm, only a fabric of inferior bulk will be obtained.

Bicomponent staple fiber having a degree of crimping of over 35% will inevitably undergo an increase in number of crimps in manufacture, and it will be difficult to control the number of crimps to less than 15 per 25 mm. Also, if a degree of crimping of over 35% is imparted, this will cause draft unevenness in the spin drafting process. If the degree of crimping is less than 15%, entangling may be reduced, but sufficient bulk will not be obtained in the fabric.

The more preferred range of degree of crimping is 20-30%. It is also desirable to maintain a degree of crimping of  $\geq 5\%$  even through the spinning process. A crimp degree/crimp number ratio of  $\geq 1.50$  is necessary to impart an appropriate degree of entangling and outstanding bulk, soft hand, compressibility, and resilience to the fabric. If that ratio is lower than 1.5, it will cause a decline in bulk.

The preferred embodiment of the above-indicated polyester bicomponent staple fiber will now be explained.

First, a combination of polymers where the two components consist of polyethylene terephthalate and the difference between their intrinsic viscosities is 0.06-0.12 is the preferred example. If the difference between their intrinsic viscosities is less than 0.06 at this time, the ability to manifest crimp will tend to decline. And if the difference is greater than 0.12, this will cause an increase in the number of crimps, which is undesirable.

As for the difference between the intrinsic viscosities of the two components, when the moisture content of the polymers prior to spinning is  $\leq 0.005\%$  and spinning is carried out under a  $N_2$  seal at a melt residence time of  $\leq 30$  min and melting temperature of  $\leq 300^\circ C$ , the difference between the intrinsic viscosities of the polymers prior to spinning is regarded as the intrinsic viscosity difference of the two components of the fiber.

Also, wool is often mixed in fabrics for fall and winter use, and since wool greatly degrades in performance under heat above  $100^\circ C$ , it is preferred that the two components are polyethylene terephthalate copolymerized with 3-6 mol% of ethylene-5-sodium sulfoisophthalate and that the difference between the intrinsic viscosities of the two components is 0.05-0.10, from the standpoint of developing crimp, in order to obtain a polyester bicomponent staple fiber that can be dyed at ordinary pressure below  $100^\circ C$  and also with a cationic dyestuff that does not stain wool.



When three-dimensional crimpability is imparted by a difference in intrinsic viscosity, the tenacity and bending strength of the staple fiber are affected by the component of higher intrinsic viscosity, and limits are often encountered when these are lowered to the levels sufficient and necessary to promote pill breakoff. Hence, in order to maintain the levels of tenacity and bending strength to the necessary and sufficient levels and to impart high crimpability, a combination of components where ethylene-5-sodium sulfoisophthalate is copolymerized in a component on at least one side and the difference between their percentage copolymerization is  $\geq 1$  mol% or where ethylene isophthalate and trimellitic acid are copolymerized for the component on at least one side and the difference in percent copolymerization from that of the other component is  $\geq 0.5$  mol%, is also a preferred example. In both cases, the tenacity and bending strength of the two components can easily be matched by making the difference between their intrinsic viscosities  $\leq 0.05$ , and the targeted number of crimps and degree of crimping can easily be imparted by providing a difference between the percentage copolymerization of each.

An example of the preferred method for producing the polyester bicomponent staple fiber with the properties of this invention will now be explained.

To obtain the three-dimensional crimpable bicomponent fiber of this invention, two polyester polymers of the above-mentioned combinations are subjected to bicomponent spinning of the side-by-side type usually adopted, and then the undrawn yarn obtained is collected to at least 100,000 denier, based on the drawn yarn, and drawn by the drawing of polyester staple fiber usually adopted. In addition, tow that manifests crimp overall can be obtained by heat treatment in a relaxed state in a tow heat-treatment machine at 100-150°C. This crimped tow is shown in Figure 3. The bicomponent staple fiber with a special crimp morphology of this invention can be produced by opening this to a uniform density with an ordered tow bar group (1), then partially eliminating the crimped section by straightening it to the target length by heat treating at intermittent or constant period lengths with embossing rollers (2), and cutting those straight sections with an EC cutter (7) interlocked with the embossing rollers. When heat treating intermittently with embossing rollers, it is preferred to perform the heat treatment at least above 180°C in order to prevent manifestation of crimp in the straight sections in the dyeing and finishing set processes. To impart straight sections and define the overall fiber length, it is preferred to first heat treat at a length equal to the total length of the straight section with embossing rollers and provide straight

sections so that the length from the center of one straight section to the center of the next straight section will be equal to the overall fiber length. In addition, the EC cutter used must be a cutter rotor that interlocks rotation with the embossing rollers and can cut to a length corresponding to the length from the center of one straight section to the center of the next straight section, that is, the overall fiber length. The precision of the cutter unit will vary according to the crimp unevenness of the crimped tow supplied and the opening unevenness at the ordered tow bars, but it must be adjusted by controlling the tow tension at the entrance of the embossing rollers and the tow tension at the exit of the embossing rollers.

To provide high crimpability when performing side-by-side bicomponent spinning, it is desirable to dispose the higher shrinkage, higher tension component in the convex shape shown in Figure 5 and to bond so that its occupancy of the outer periphery of the fiber cross section will be in the range of 30-50%. If this range is deviated from, the ability to manifest crimp will decline, and sometimes crimping will not be obtained even by heat treatment in a relaxed state after drawing.

#### Effects of the invention

Firstly, there is a straight section on at least one end of the fiber as indicated above, so this invention can provide outstanding spinnability and spun yarn quality even if polyester bicomponent staple fiber in which three-dimensional crimp is revealed in a high number of crimps and high degree of crimping is used.

In addition, the straight section does not manifest crimp by a heat treatment of  $\leq 180^{\circ}\text{C}$ , so even if this polyester bicomponent staple fiber is loose-fiber dyed, it will not manifest crimp, and even if spun after loose-fiber dyeing, spinnability is never lost.

Secondly, the crimped section apart from the straight section is provided an appropriate number of crimps and degree of crimping, so the fabric obtained using this bicomponent staple fiber has outstanding hand, bulk, softness, and resilience.

Thirdly, because there is a straight section on at least one end, preferably both ends, of the fibers, most of the fluff that occurs on the spun yarn and surface of the cloth is straightened, and the fluff hardly tangles. Moreover, the staple fibers present on the inside of the spun yarn have a high degree of crimping, so the slip resistance is great. In addition, the bending strength of the

staple fiber is weakened, so even if pills form on the cloth surface, they break off easily and therefore pilling resistance is outstanding.

The polyester bicomponent staple fiber of this invention is effective in the fabric field of fall and winter clothing in which puffing of the cloth is demanded. In particular, it can be favorably used in the fabric fields of 100% polyester and wool blends.

This invention will now be explained in further detail with practical examples.

The physical properties in the practical examples were measured as follows.

#### A. Bending strength

Bending strength is represented by the number of bending times until the single fiber breaks when subjected to flexing abrasion at a bending rate of 60 times/min under a load applied to the single fiber of 200 mg/denier using the flexing abrasion resistance measuring instrument of F. Dillman.

#### B. Number of crimps, degree of crimping

A crimp measuring instrument was used to measure the number of crimps per 25 mm when a load of 2 mg/denier was applied to a single fiber. Also, the length of a single fiber ( $\lambda_0$ ) was measured by applying a load of 2 mg/denier to a single fiber, and then the length ( $\lambda$ ) when a load of 300 mg/d was applied was measured, and the degree of crimping (%) was found from the following equation.

$$\{(\lambda - \lambda_0)/\lambda_0\} \times 100$$

#### Practical Example 1

Undrawn yarn was obtained by spinning combinations of polyethylene terephthalate polymers having intrinsic viscosities of 0.57 (A), 0.47 (B) and 0.66 (C), 0.52 (D) at a discharge rate of 60 g/min per component for a total of 120 g/min for both components (component ratio 50/50) and spinning rate of 1,300 m/min using a side-by-side type bicomponent spinneret having 96 holes. After this undrawn yarn had been drawn, tow was made by collecting that so as to become 200,000 denier and was drawn by a ratio of 3.5 through a bath at a liquid temperature of 90°C. Next, the moisture content was wrung to  $\leq 20\%$  and collectibility lightly imparted to the tow between crimper rolls, following which three-dimensional crimp was manifested by heat treating in a relaxed state at 140°C for 15 min.

First, part of the crimped tow of the polymer combination (A)/(B) was cut, as is, to 76 mm for use as raw stock (1) for comparison.

Next, the remaining crimped tow of polymer combination (A)/(B) and the crimped tow of polymer combination (C)/(D) were heat treated for a total of 3 sec at a temperature of 200°C with the length of the straightening heat treatment zone of the embossing rollers set to 30 mm to impart intermittent straight sections so that the distance from the center of a straight section to the center of the next straight section was 76 mm. Next, the straight sections were cut with an EC cutter interlocked with the embossing rollers to obtain raw stocks (2) and (3) having an overall fiber length of 76 mm and total straight length of 30 mm. The staple fibers (1)-(3) obtained had the properties shown in Table 1.

Table 1

Raw Stock Standard No.		(1) (Comparative Example) (A)/(B)	(2) (Practical Example) (A)/(B)	(3) Comparative Example (C)/(D)
Polymer combination				
Single fiber denier	d	3.0	3.0	3.0
Tenacity	g/d	4.2	4.2	5.0
Elongation	%	4.0	4.0	38
Bending strength	times	1,100	1,100	2,400
Number of crimps of crimped section	no./25 mm	13.5	13.5	17.5
Degree of crimping of crimped section	%	26	26	32
Degree/number ratio of crimped section	—	1.9	1.9	1.8
Length of shorter straight section at end of fiber (S <sub>1</sub> )	≥ 5 mm	%	90	92
	0 to < 5	%	10	8
Average intrinsic viscosity		0.50	0.50	0.57

The results of evaluating spinnability and yarn quality using the three raw stocks (1)-(3) above are shown in Table 2.

Table 2

Raw stock Standard No.			(1) (Comparative Example)	(2) (Practical Example)	(3) (Comparative Example)
Spinnability in carding process	Lap licking		No	No	Sometimes
	Web vibration, breaks		Occasional breaks	No	Vibration
	Web nep		Many	Very few	Few
	Continuous operability		Difficult	Possible	Required constant supervision
Yarn quality	Count	Nm	1/48	1/48	1/48
	Uster evenness	%	17.0	14.0	14.5
	No. of yarn defects (nep, thick, thin)	no./1,000 m	315	70	102

The raw stock of Standard No. (2), which is this invention, was satisfactory in both carding process throughput and yarn quality.

The spun yarns of (1), (2), and (3) in above table were processed into two-ply yarn, then made into right-hand 2/2 twill (serge) weave. After dyeing and finishing set, shearing and

singeing were performed to give a woven fabrics with a clear cut finish. The properties of the woven fabrics are shown in Table 3.

Table 3

Standard No.		(1) (Comparative Example)	(2) (This Invention)	(3) (Comparative Example)
Basis weight	g/m <sup>2</sup>	250	250	250
Bulk	cm <sup>3</sup> /g	2.92	2.80	2.82
Compressibility	%	25	24	20
Compression modulus	%	81	83	78
ICI pilling resistance	Grade	1-2	4	2

As shown in the above table, the woven fabric of Standard No. (2), which is this invention, excelled in pilling resistance, and in terms of fabric properties, too, exhibited properties equal to those of the conventional bicomponent staple manifested in high number of crimps and high degree of crimping, and provided a very wool-like hand. By contrast, the woven fabric of Standard No. (3) was inferior in pilling resistance, and in terms of hand, was a hard fabric.

#### Practical Example 2

The staple fiber of Standard No. (2) of Practical Example 1 was dyed at 130°C and then dried under dry heat at 120°C. Crimping was not found in the straight sections at this time, and the staple fiber had almost the same morphology as before dyeing. As a result of spinning after applying 0.35% of spinning lubricant to this dyed loose fibers, there was little nep or web unevenness in the same carding process as used in Practical Example 1, and the quality of the spun yarn was of the same level as ordinary two-dimensional crimp staple fiber and was outstanding.

#### Practical Example 3

Each polymer combination of polyethylene terephthalate (E) having an intrinsic viscosity of 0.50 as the component on one side with polyethylene terephthalate (F) obtained by copolymerizing 1.0 mol% of ethylene isophthalate having an intrinsic viscosity of 0.50 and 1.0 mol% of trimellitic acid and polyethylene terephthalate (G) obtained by copolymerizing 5 mol% of ethylene isophthalate having an intrinsic viscosity of 0.50 as the other component was spun using the same side-by-side bicomponent spinneret as used in Practical Example 1 at a discharge rate of 44 g/min per component, for a total of 88 g/min for both (component ratio 50/50) at a spinning rate

of 1,200 m/min. After the undrawn yarn obtained had been drawn, it was collected so as to be 200,000 denier and drawn at a ratio of 3.2 by passing it through a bath at a liquid temperature of 75°C. Next, it was lightly wrung between crimper rolls so that the moisture content became  $\leq 20\%$ , and the tow was collected. Then the tow was heat treated in a relaxed state at 140°C for 15 to manifest three-dimensional crimp. The properties of the single fibers of the crimped tow obtained are shown in Table 4.

Table 4

Crimped Tow Standard No. Polymer combination		(4) Practical Example (E)/(F)	(5) (Comparative Example) (E)/(G)
Single fiber denier	d	2.5	2.5
Tenacity	g/d	3.5	4.0
Elongation	%	35	48
Bending strength	times	350	600
Number of crimps	per 25 mm	13.0	11.0
Degree of crimping	%	20.0	14.0
Crimp degree/crimp number ratio	—	1.6	1.3

As shown in the above table, the targeted properties were obtained for polymer combination (E)/(F), but the crimping characteristics of polymer combination (E)/(G) were insufficient.

Then polymers (E), (F), and (G) were spun individually, and the results of comparing the orientation tension and the shrinkage of the drawn fibers when drawn at the same temperature and draw ratio are shown in Table 5.

Table 5

Polymer Standard No.		(E)	(F)	(G)
Draw ratio	—	3.2	3.2	3.2
Draw temperature	°C	75 (liquid bath)	75 (liquid bath)	75 (liquid bath)
Orientation tension	g/d	1.0	1.3	0.8
Boiling shrinkage	%	9	14	17

As this table shows, the orientation tension and shrinkage of (F) were both higher than that of polymer (E), whereas the boiling shrinkage of (G) was higher, but its orientation tension

was lower, so this shows that in bicomponent fiber of polymers (E)/(G) the two characteristics cancel each other out and sufficient crimping characteristics are not imparted.

Staple fibers with the varied total straight lengths and cut lengths shown in Table 6 were prepared using the crimped tow of Standard No. (4) combining polymers (E)/(F).

Table 6

Raw Stock Standard No.			(4)-(1) (Comparative Example)	(4)-(2) (Practical Example)	(4)-(3) (Practical Example)
Total straight length	mm		15	15	20
Cut length (overall fiber length)	mm		44	51	64
Total straight length/overall fiber length	%		34	29	31
Length of shorter straight section of fiber ends	≥ 5 mm	%	75	80	85
	0 to < 5 mm	%	25	20	15
Average intrinsic viscosity			0.48	0.48	0.48

The results of a comparative evaluation of spinnability in the carding process using the above staple fibers are shown in Table 7.

Table 7

Raw Stock Standard No.	(4)-(1)	(4)-(2)	(4)-(3)
Lap licking	Frequent	Infrequent	No
Card web vibration, breaks	Frequent	Infrequent	No
Card web nep	Few	Few	Few
Continuous operability	Impossible	Possible	Possible

The staple fiber of (4)-(1) having a cut length of 44 mm could not be spun.

Standards (4)-(2) and (4)-(3) in the above table were then made into 2/48 spun yarns through a spinning process. As for yarn quality, both Uster unevenness and number of yarn defects were satisfactory, so the yarns were made into right-hand 2/2 twill (serge) weave, and dyeing and finishing set and also light napping were applied to produce woven fabrics. The woven fabrics obtained from the staple fibers of (4)-(2) and (4)-(3) both had grade 4 pilling resistance by the ICI method and suitable for practical use, and they exhibited the outstanding



soft hand, flexibility, compressibility, bulk, and resilience characteristic of three-dimensional crimp bicomponent staple fiber.

#### Practical Example 4

Undrawn yarn was obtained by spinning a polymer combinations of polyethylene terephthalate copolymerized with 5 mol% of ethylene-5-sodium sulfoisophthalate having intrinsic viscosities of 0.60 (H) and 0.52 (I) at a discharge rate of 44 g/min per component, for a total of 88 g/min for both (component ratio 50/50), and a spinning rate of 1,200 m/min using the same side-by-side bicomponent spinneret as used in Practical Example 1.

This undrawn yarn was drawn and then collected so as to become 200,000 denier, drawn by a ratio of 3.2 by passing it through a bath at a liquid temperature of 80°C, and lightly wrung between crimper rolls so that the moisture content became  $\leq 20\%$ . After the tow had been collected, it was heat treated in a relaxed state at 140°C for 15 min to manifest three-dimensional crimp. The properties of the single fibers making up this crimped tow were a fineness of 2.5 denier, crimp number of 11.5 per 25 mm, degree of crimping of 19.5%, crimp degree/crimp number ratio of 1.70, tenacity of 3.2 g/d, elongation of 38%, and bending strength of 500 times.

This crimped tow was imparted straight sections by the same method as in Practical Example 1, changing only the temperature condition to 190°C, and then the straight sections were cut to obtain staple fiber (5) having a fiber length of 76 mm. The total straight length of the staple fiber this time was 30 mm, and the percentage of shorter straight sections of the fiber ends having a length of  $\geq 5$  mm was 88% and the percentage having a length of 0 to less than 5 mm was 12%. Also, the average intrinsic viscosity of this bicomponent staple fiber was 0.52.

Sixty percent of this staple fiber and 40% of wool cut to 76 mm with an attenuator were mixed and spun to obtain 2/52 spun yarn. This time, too, there was little nep generation and web unevenness in the carding process, spinnability was good, and yarn quality was also satisfactory.

The polyester and wool of this spun yarn were dyed with cationic dye and acid dye in the skein state at a temperature of 90°C. Then weft knitted fabric was made with a structure of  $2 \times 2$  ribs and 12 gauge. The fabric obtained was sufficiently settable by hoffman setting, and its ICI pilling resistance was grade 3 and suitable for practical use. It also showed outstanding bulk and dimensional stability. For purposes of comparison, monocomponent staple fiber of polyethylene terephthalate copolymerized with 5 mol% of ethylene-5-sodium sulfoisophthalate having an

intrinsic viscosity of 0.50 (fineness of 2.5 d, tenacity of 3.0 g/d, elongation of 40%, bending strength of 380 times, two-dimensional crimp with 12 crimps per 25 mm and a degree of crimping of 13%) was similarly spun, dyed, and knitted. The pilling resistance of the weft knit fabric was grade 1-2, and bulk was also inferior.

#### Practical Example 5

Polyethylene terephthalate polymer (E) having an intrinsic viscosity of 0.50 and polyethylene terephthalate polymer (J) copolymerized with 1.8 mol% of ethylene-5-sodium sulfoisophthalate and having an intrinsic viscosity of 0.50 were used to obtain the bicomponent staple fibers shown in Table 8 having a fiber length of 76 mm and with a total straight length of 30 mm at one or both ends of by the spinning, drawing, heat treating, and straightening methods and conditions shown in Practical Example 4.

This bicomponent staple fiber had an average intrinsic viscosity of 0.48.

Table 8

Raw stock Standard No.		(6) (This Invention)
Single yarn denier	d	2.5
Tenacity	g/d	3.4
Elongation	%	37
Bending strength	times	480
Number of crimps of crimped section	per 25 mm	14.0
Degree of crimping of crimped section	%	27.0
Degree/number ratio of crimped section	—	1.9
Length of shorter straight section at end of fiber	≥ 5 mm	% 93
	0 to < 5 mm	% 7

Spun yarn of 1/48 was made by blending 70% of the above staple fiber and 30% of wool cut to 76 mm with an attenuator. Spinnability and yarn quality were satisfactory, so this spun yarn was used to make a right-hand 2/2 twill (piera [spelling not confirmed]) weave. Clear cut (shearing/singeing) finish and milling (float napping) finish were applied to obtain woven fabrics of two standards. The ICI pilling resistance of the clear-cut finish fabric was grade 4 and that of the milling finished fabric was grade 3, and they were suitable for practical use.

#### 4. Brief Description of the Figures

Figure 1 and Figure 2 show the crimp morphology of the polyester bicomponent staple fiber of this invention.

Figure 3 is a simplified drawing that shows an example of the fiber of the production method and each process of this invention, and Figure 4 is a cross section at X-X' of the embossing rollers. Figure 5 is an example of the bicomponent morphology preferred in this invention.

- (1) Crimped tow
  - (2) Dancer rollers
  - (3) Ordered tow bars
  - (4) Embossing rollers
  - (5) Tow path control guides
  - (6) Tow width control guide
  - (7) EC cutter rotor
  - (8) Crimped tow
  - (9) Tow with straight sections provided intermittently
  - (10) Staple fiber with the straight sections cut
- A High-shrinkage, high-tension component  
B Low-shrinkage, low-tension component

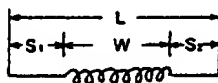


Figure 1

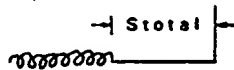


Figure 2

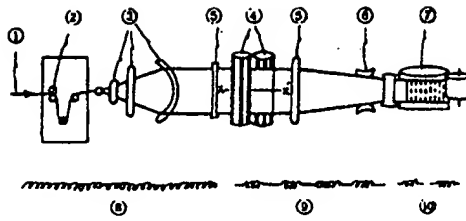


Figure 3

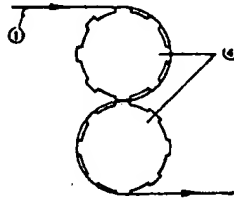


Figure 4

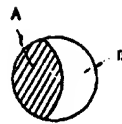


Figure 5